FIELD TEST OF AN EXPERIMENTAL BRACKETING SIGHT FOR THE 12-GAGE RIOT SHOTGUN

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Monterey, California

THESIS

FIELD TEST OF AN EXPERIMENTAL
BRACKETING SIGHT FOR THE
12-GAGE RIOT SHOTGUN

by

Richard Duane Read

September 1974

Thesis Advisor: J.K. Arima

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Field Test of an Experimental Bracketing Sight
for the
12-Gage Riot Shotgun

by

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ABSTRACT

A field experiment was conducted to determine whether a circular bracketing sight mounted on a standard M12 12-gage riot shotgun could enhance the effectiveness of the weapon by reducing shot-pattern radial miss distance and increase the number of pellet hits on target in a short-range, quick-reaction environment against a stationary target. Circular bracketing sights of 1.232 and 2.464 inches in diameter were used. An unmodified M12 sight was also tested for comparison. Human silhouette targets at ranges of 20 and 40 yards were exposed for periods of 2.5 seconds. Subjects, six military personnel, engaged the targets with each sight and at each range. Results showed a significant decrease in radial miss distance with the large bracketing sight and a significant increase in pellet hits on target with both bracketing sight configurations. A significant preference for the small bracketing sight was noted among the subjects.

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I. BRIEF

A. PROBLEM

To improve the effectiveness (hit capability) of the soldier armed with the 12-gage riot shotgun in short-range, quick-reaction civil disturbance operations and to minimize the possibilities of unintentional casualties due to shot pattern dispersion.

B. PROCEDURE

Six military personnel with previous shotgun experience were used as Subjects (Ss) and were trained in the use of two circular bracketing sights differing only in size. Each of these sights was mounted over the bead sight of a M12 12- gage riot shotgun.

Testing was conducted on a known-distance rifle range under normal daylight conditions. The range was located in sparsely vegetated, level terrain. Firing positions were established at each of two ranges, 20 and 40 yards. Testing was conducted with the standard military load #00 buckshot consisting of 9 pellets per round. Testing consisted of determining the capability of the Ss to hit a standard silhouette target while also minimizing radial distance from center of target to center of mass of the shot pattern. The target was exposed for 2.5 seconds for each single-shot engagement. Three methods of fire were utilized: bead aiming with the standard sight, bracket

aiming with a 2.464 inch diameter (large) circular sight, and bracket aiming with a 1.232 inch diameter (small) circular sight. All firing was done from a standing position and each S fired a total of 24 test rounds.

The performance of the Ss was analyzed to determine significant differences in hit capability and radial miss distance between sight configurations and range. In addition, formal post-test questioning of the Ss was analyzed to determine an overall S's profile, comments concerning the experiment, and preferences for the three sight configurations.

C. FINDINGS

The large circular bracketing sight was found to significantly reduce the radial miss distance of the rounds fired. The unmodified sight, while less effective than the large sight, was found to provide a significantly smaller radial miss distance than the small circular bracketing sight. The mean miss distances were 16.84 inches for the unmodified sight and 12.11 and 19.15 inches for the large and small sights, respectively. The two circular bracketing sights both provided a significantly larger number of pellet hits on the target than did the unmodified sight. The large sight achieved 46.3% targets hits, the small sight 45.1% and the unmodified sight 29.4%. No significant agreement among Ss preferences for the sight configurations was noted at 20 or 40 yards, however overall, the Ss expressed a significant preference for the small sight.

D. UTILIZATION OF FINDINGS

The development of a circular bracketing type sight for the M12 riot shotgun should aid in the reduction of radial miss distance for rounds fired and in the increase in the number of pellets striking the intended target. This would provide the firer greater control over his area of engagement and lessen the chances of obtaining unintentional casualties during the conduct of civil disturbance type operations.

In addition, the use of the bracket aiming procedure associated with the circular sight configuration could readily be incorporated into present shotgun training and familiarization programs. Training and familiarization firing with the circular bracketing type sights may be accomplished in two to three hours.

II. BACKGROUND

A. CONCEPT DEVELOPMENT

During the past decade, the use of military forces in quelling civil disturbances has become a common occurrence. Doctrine and training have continually been updated to develop a maximum effectiveness in this type of mission. Equipment has also been improved, however, the 12-gage riot shotgun remains a weapon of prime importance in riot control operations. One of the primary advantages of the shotgun, area fire, is also presently one of its major drawbacks.

On 18 May 1970 in Augusta, Georgia, six persons were killed by shotgun blasts fired by police forces during a racial riot. Two days later two students were killed by shotgun blasts during a civil disturbance at Jackson State University in Jackson, Mississippi. In both cases, law enforcement officers stated shots were fired only in an attempt to wound fleeing suspects [2].

The nature of the riot shotgun is such that it is fired primarily by pointing rather than aiming in the sense that a rifle is aimed. Rifle-type sights are not found on riot shotguns in the military inventory. The basic ammunition load for the M12 12-gage riot shotgun is #00 buckshot which can cause fatalities at 300 yards despite the fact that the majority of civil disturbance engagements occur at ranges

less than 30 yards [1]. Maximum ranges for #00 buckshot have been determined to be in excess of 740 yards [6]. Both #7½ and #9 birdshot are recommended ammunition loads for firing into crowds [3], but both have even greater lateral dispersion than #00 buckshot [12].

One proposed method for handling the dispersion problem was to modify the ammunition's ballistic characteristics, thus tightening the dispersion pattern. This method has generally been disregarded due to excessive costs and the fact that lessening the dispersion pattern would simply make the shotgun more of a point-target weapon, when an adequate point-target weapon exists in the military arsenal, the M16A1 rifle.

A second proposal involved the use of lighter metals in the pellets in order to restrict range effects and to reduce the pellet lethality. This method was deemed generally unsatisfactory due to the necessity for a variety of shot loads as the lighter materials would not penetrate heavy clothing and would thus have no effect.

An alternative proposal involved a sighting system which would enable the firer to quickly and more accurately center the shot pattern on the intended target, thus minimizing the number of pellets missing the target and being free to strike unintentional targets.

B. PREVIOUS RESEARCH

Research conducted by Kemple and McKinney [8], and Fisher and McLeskey [5] demonstrated the effectiveness of circular bracketing type sights on the M16A1 rifle when firing on both stationary and moving targets using the standard Army "quick-fire" technique. The reasoning behind the use of bracketing sights was to enable the firer to quickly place the target in the sight picture and to have a sight the firer could effectively use while still maintaining visual contact with the target, thereby lessening focal distance problems inherent in "peep" sights. Their research indicated a significant increase in target hits using circular brackets of 2.64 and 1.32 inches in diameter. Kemple and McKinney noted a 23% increase in the number of target hits when using the small circular sight over the unmodified and large circular sights when firing at stationary targets exposed for 1.6 seconds at ranges of 25 and 50 yards. Fisher and McLeskey noted increases in excess of 140% when using the same size circular sights on moving targets at the same two ranges.

C. CURRENT RESEARCH

The findings of Kemple and McKinney [8] and Fisher and McLeskey [5] suggest that a circular bracketing type sight might significantly increase the firer's ability to center the shot dispersion pattern on the target, thus minimizing the number of shot pellets missing the target and being free

to strike unintentional targets. The "quick-fire" technique used in the referenced research is highly similar in nature to the standard shotgun firing technique and the ranges used are of the same order as those generally encountered in civil disturbance operations. It was thus proposed that a circular bracketing type sight should be field tested using the M12 12-gage shotgun and #00 buckshot. The current research was undertaken to provide information to assist in answering the following question: Would the circular bracketing sight system enable a shotgun firer to maintain hit capability while also significantly reducing the radial distance to center of mass of the shot pattern?

III. PROCEDURE

The sighting devices used for this experiment were the unmodified (bead) sight on the M12 riot shotgun, and the two different sized circular bracketing sights. Figures 1 and 2 depict the configurations and the component parts of the bracketing sights. One M12 shotgun was fired in an unmodified mode, while two others were modified by the addition of the circular bracketing sights as depicted in Figures 3 through 6. Two measures were used to assess the effectiveness of the sight configurations. These were the mean radial miss distance of the center of shot group for each condition and the percent of pellet hits on the targets.

The fixed target range, utilized for testing the sight configurations, was located at Fort Ord, California and was situated on level, open terrain with only sparse vegetation. All testing was conducted under normal daylight conditions. Standard Type E silhouette targets were used and were mounted on M31A1 target raising devices. The raising mechanisms and control wiring were an integral part of the range used and control panels were permanently installed in a control tower to the rear of the firing lines. Cardboard panels, measuring 6 X 10 feet, were mounted behind each silhouette in order to record all pellets fired. Six firing points were established perpendicular to the line of targets, three each at 20 and 40 yards. One target was presented for any single

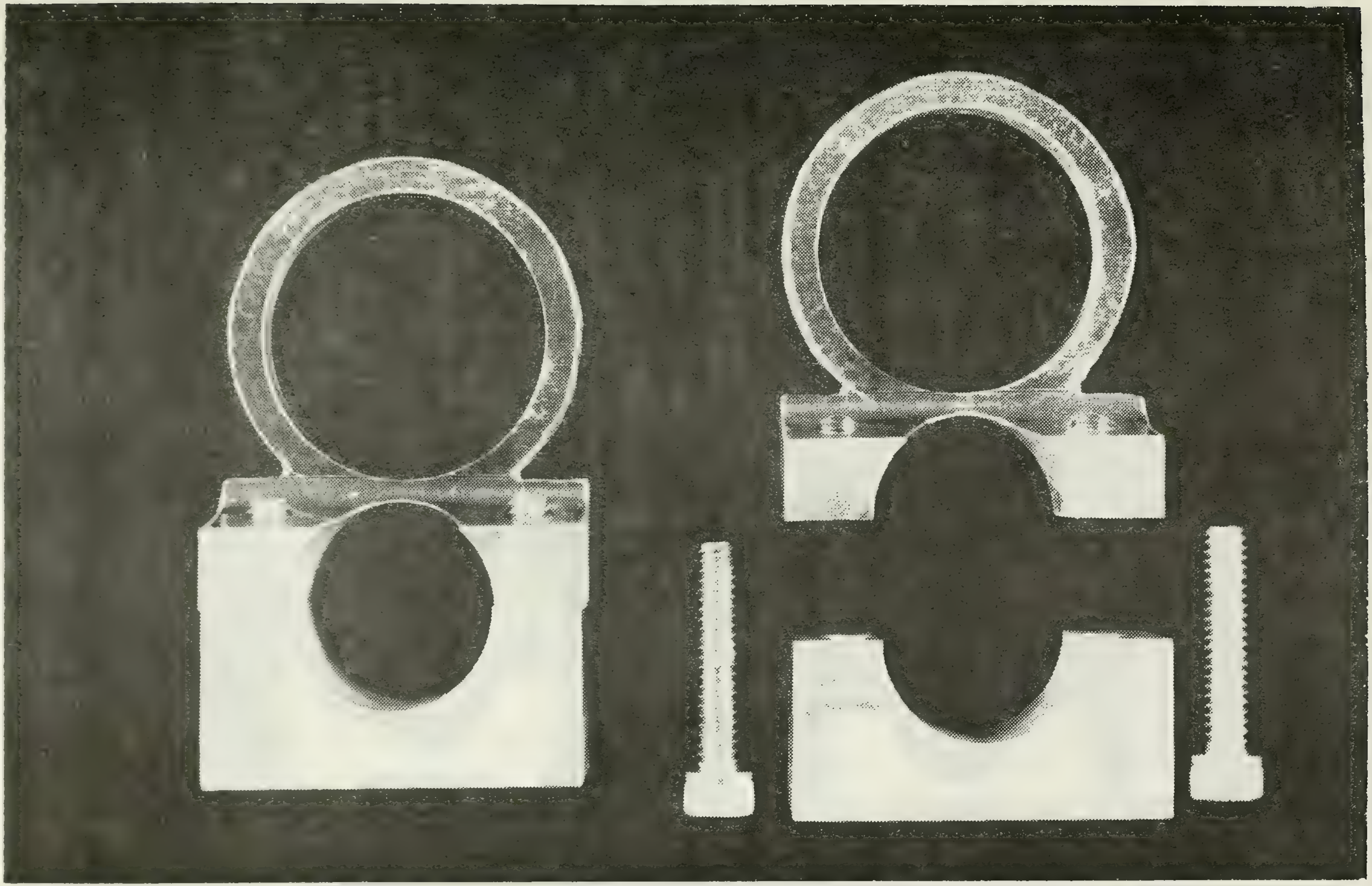

Figure 1. Component Parts of Small Bracketing Sight

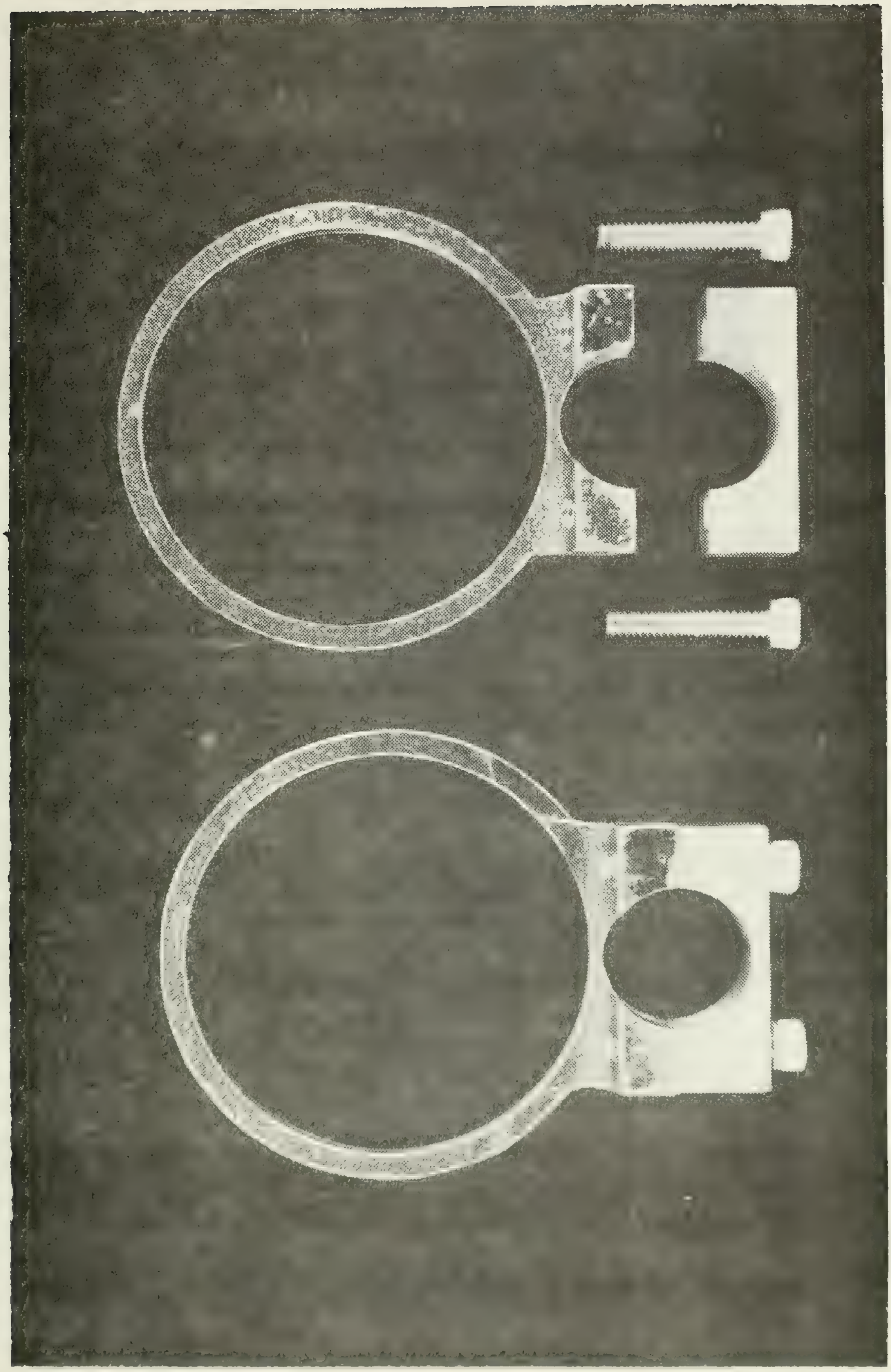

Figure 2. Component Parts of Large Bracketing Sight

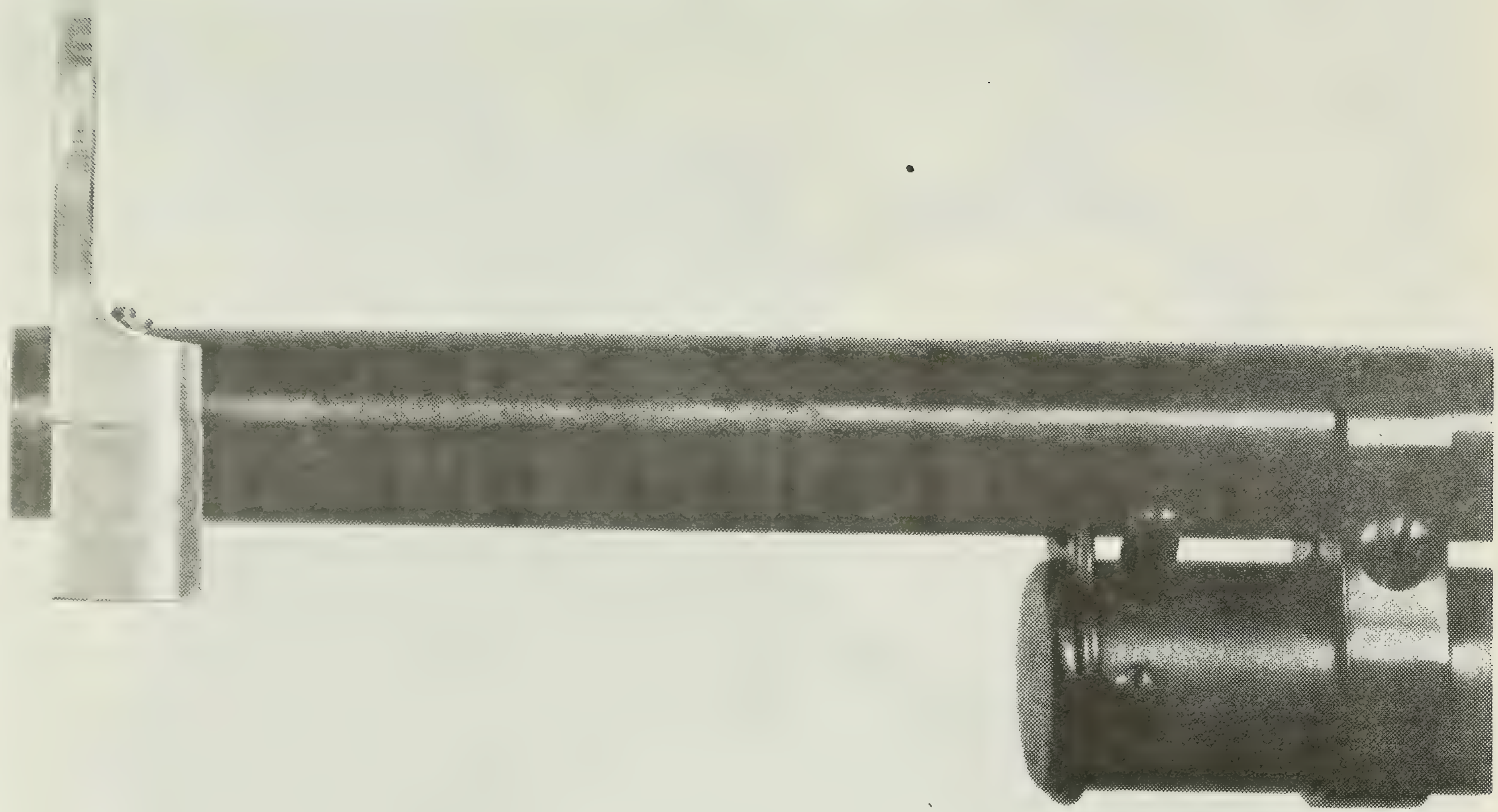

Figure 3. Side View, Small Bracketing Sight

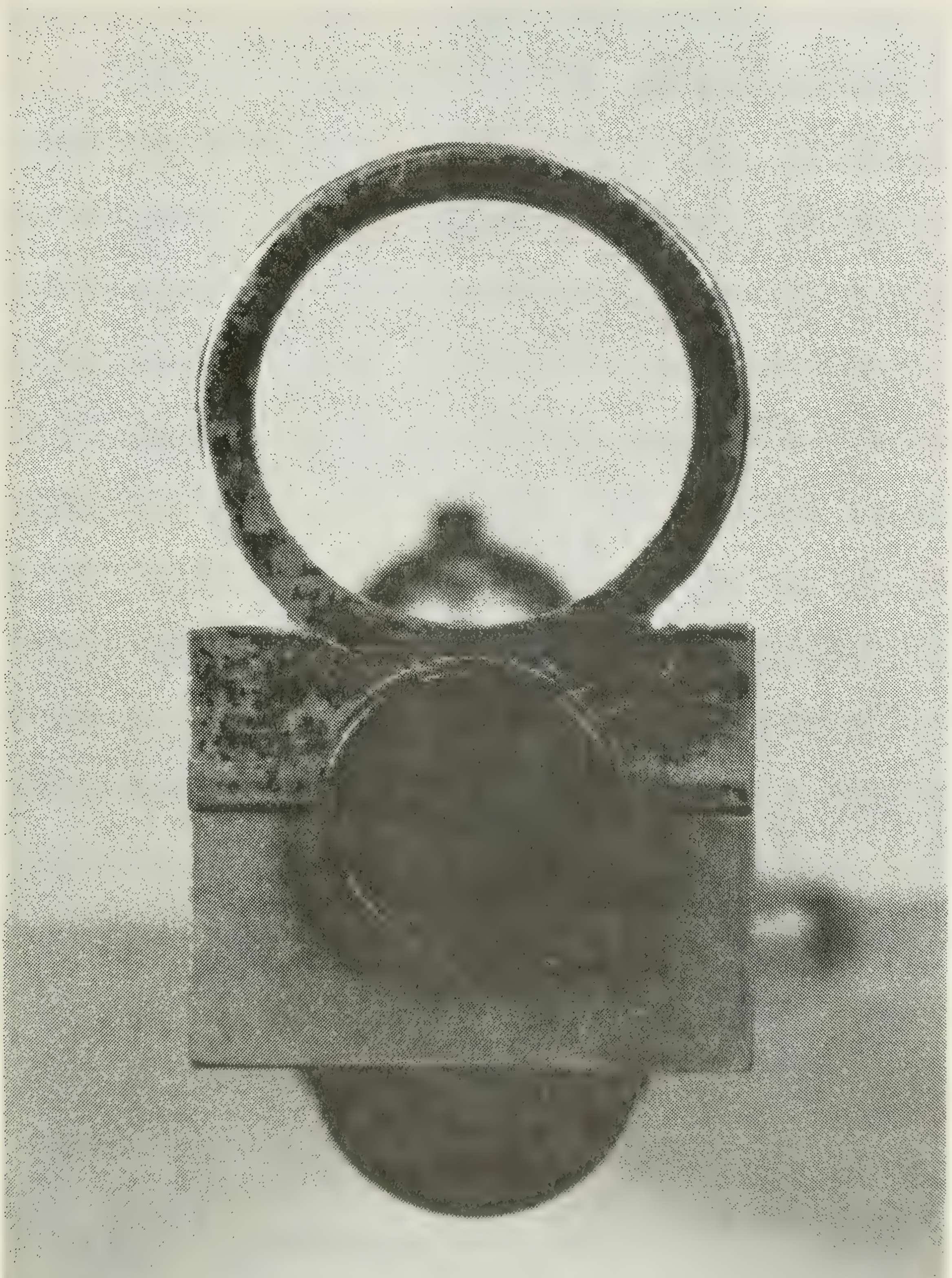

Figure 4. Front View, Small Bracketing Sight

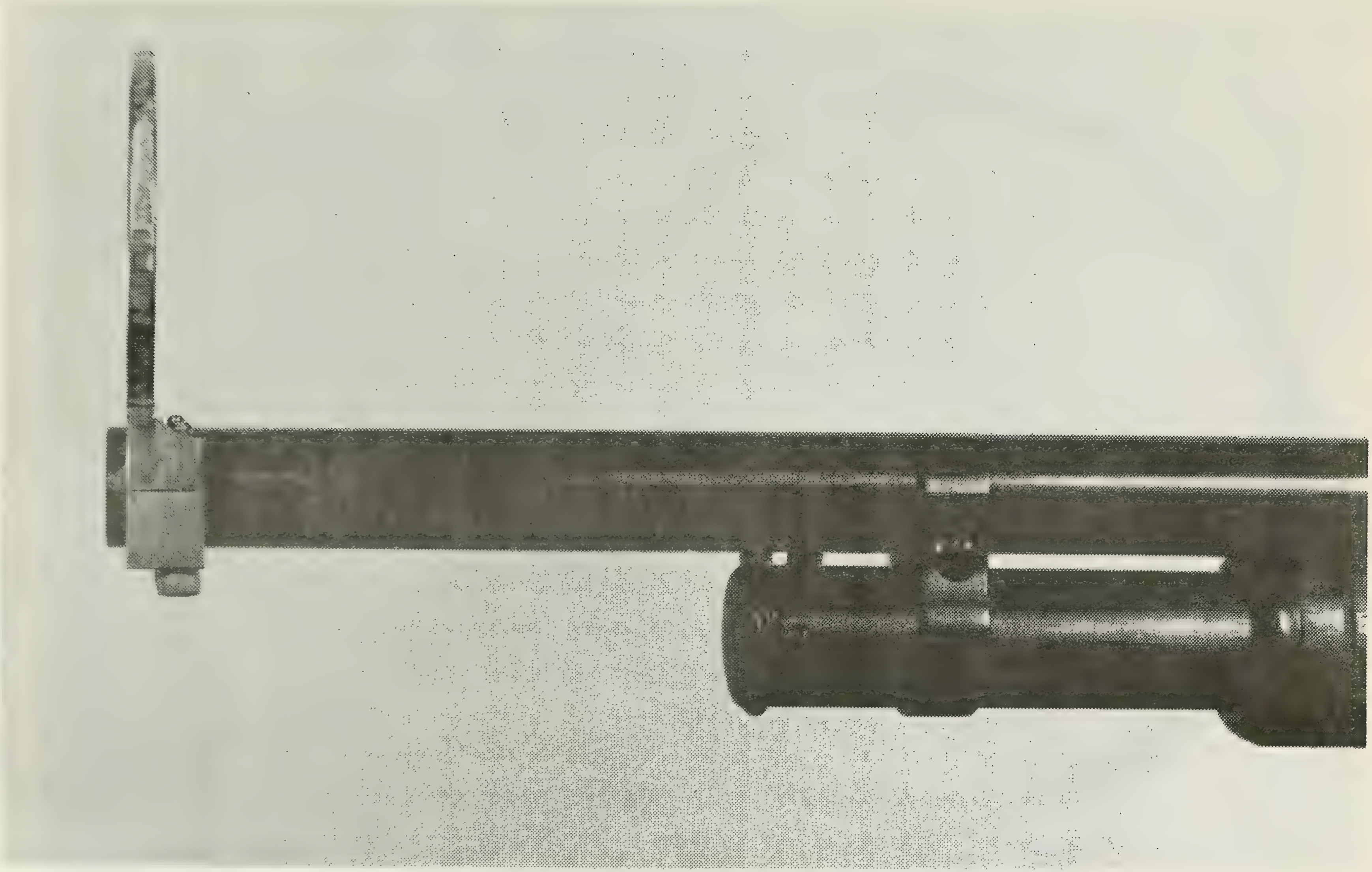

Figure 5. Side View, Large Bracketing Sight

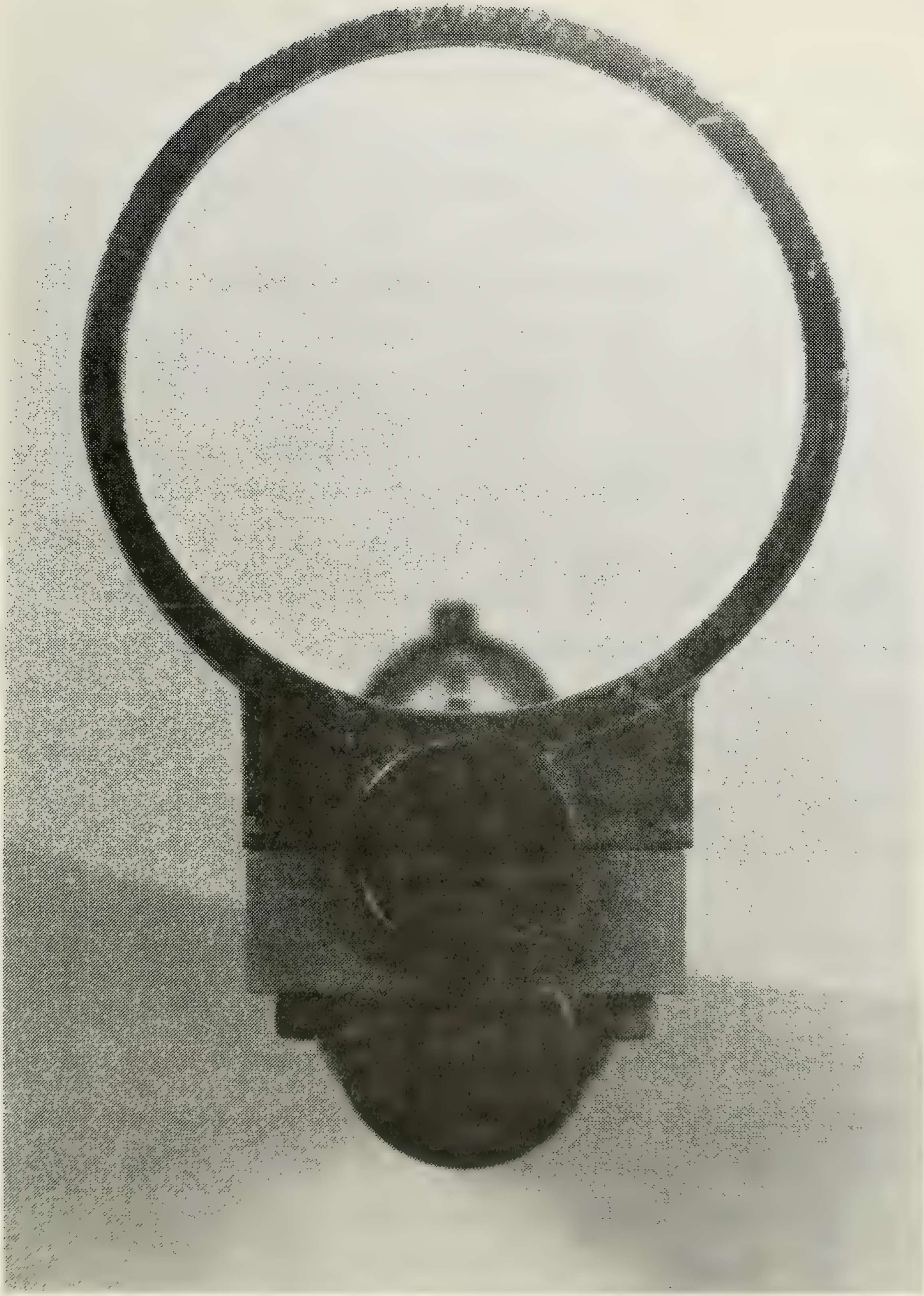

Figure 6. Front View, Large Bracketing Sight

engagement on command. Exposure time of the target to the firer was 2.5 seconds.

The experiment was conducted using six military personnel as Subjects (Ss). When the Ss arrived at the range, they were given an orientation briefing which included the background and purpose of the experiment as well as a demonstration showing the range configuration and operation. Following this orientation, instruction was given on the operation of the weapons, the use of the modified sights, and safety precautions to be observed on the range. Familiarization firing was then conducted which provided an opportunity for each S to fire three rounds with each of the sight configurations in order to familiarize himself with the proper body-weapon-target alignment. The procedures for the conduct of the actual testing were then fully explained.

Each S was then assigned a firing number. The testing was conducted by assigning Ss, by number, to firing positions with specified sight configurations. Each S fired four rounds at each range with each of the three sight configurations. After each round was fired, the range was closed and personnel proceeded down range to obtain data measurements and to patch target panels and mark targets. Upon the completion of the firing of four rounds by a firing order, a new firing order was designated, with range and sight configuration specified. The Ss' firing order, sight

order, and range order were all randomized. Testing was completed when all Ss had fired each of the three sight configurations at both of the test ranges.

When all firing had been completed, a questionnaire was given to each of the Ss eliciting profile data, comments concerning the conduct of the test, and personal preferences among the three sight configurations.

IV. RESULTS

The data were analyzed to determine if any significant differences existed among the standard sight, the small circular bracketing sight, and the large circular bracketing sight in short-range, stationary target engagements using the M12 riot shotgun in daylight conditions. Additionally, it was desired to determine if any significance which did occur was consistent over changes in range and to determine if any significant learning effects were present during the conduct of the experiment. The overall results of the radial distance data are presented in Table I and the results of the target hit data are presented in Table II.

A. SIGHT DIFFERENCES

The large bracketing sight was found to be significantly better than either of the other two configurations in reducing the radial distance from center of target aiming point to center of mass of the shot burst. However, of the remaining two configurations, the unmodified sight was found to be significantly better than the small sight. The data, combined over ranges, demonstrated a mean radial miss distance of 12.11 inches for the large bracketing sight, 16.84 inches for the unmodified sight, and 19.15 inches for the small bracketing sight. The secondary measure of effectiveness used was the number of pellet hits on the target. In this case

TABLE I. SUMMARY OF RESULTS BASED ON MEAN RADIAL MISS DISTANCE

Mean Radial Miss Distance (inches)

Sight	Range (yards)		
	20	40	Overall
Unmodified	13.73	19.96	16.84
Small	18.38	19.93	19.15
Large	10.48	13.75	12.11
Overall	14.19	17.88	16.04

Note: #00 Buckshot pattern diameter at 40 yards = 30 inches
20 yards = 15 inches

TABLE II. SUMMARY OF RESULTS BASED ON TARGET HITS

Target Hits (Percent)

Sight	Range (yards)		
	20	40	Overall
Unmodified	44.4	14.4	29.4
Small	64.4	25.9	45.1
Large	59.7	32.9	46.3
Overall	56.2	24.4	40.3

Note: Total of 144 rounds (1296 pellets) were fired

it was found that the two circular bracketing sights achieved significantly more hits on the silhouette than did the unmodified sight. The data, again combined over ranges, demonstrated 29.4% hits for the unmodified sight, and 46.3% and 45.1% hits for the large and small bracketing sights, respectively. These results cannot be construed as inconsistent due to the fact that radial distance measurements were taken without regard to direction, therefore a sizable number of target hits did occur at a large radial distance to the center of mass of a shot pattern, as in a burst which struck the target on line, but below the aiming point.

B. INTERACTIONS

A significant interaction ($\alpha = 0.05$) was noted for a combination of range and sight configuration variables in the analysis of radial miss distance. This significance is due primarily to the large increase in mean radial miss distance for the unmodified sight in going from 20 to 40 yards. Whereas the unmodified sight had a noticeably smaller mean radial miss distance at 20 yards than did the small circular bracketing sight, there was virtually no difference between the two sights at 40 yards as indicated in Figure 7. For the data on target hits, the interaction was not found to be significant, indicating those results were conclusively consistent over the ranges considered, as shown in Figure 8.

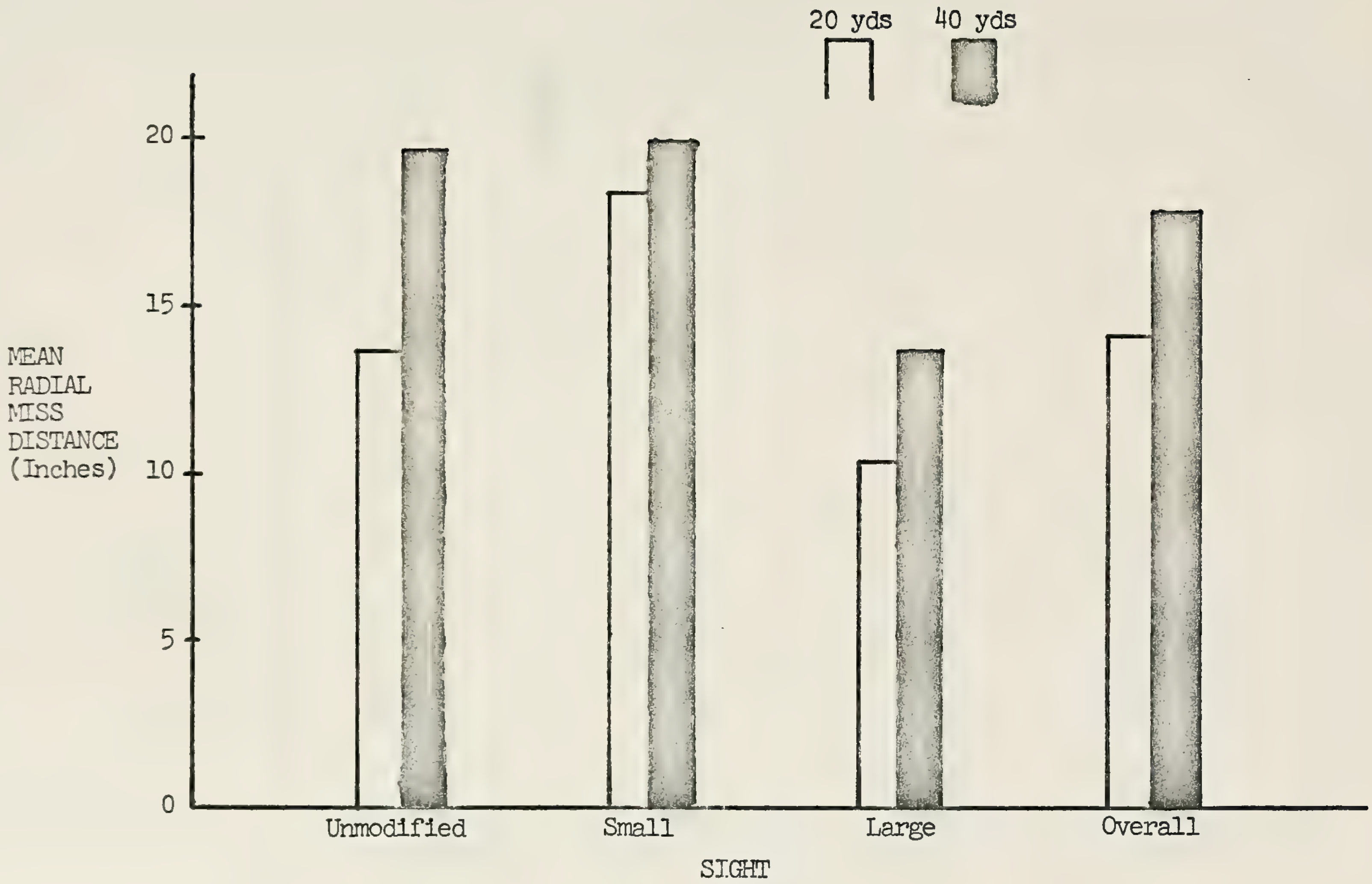

Figure 7. Mean Radial Miss Distances by Sights and Ranges

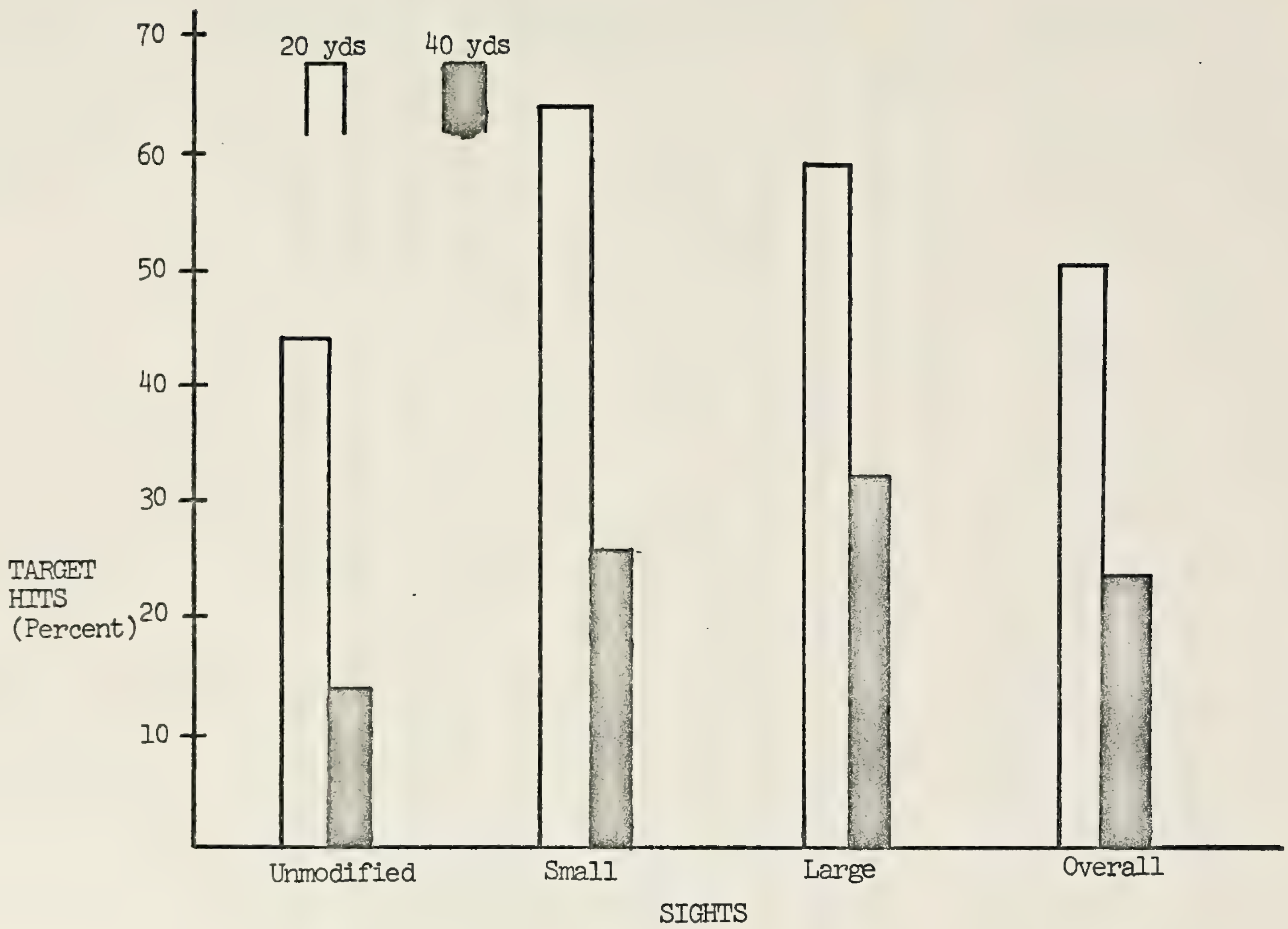

Figure 8. Percent Target Hits by Sights and Ranges

C. RANGE DIFFERENCES

Performance at the 20 yard range was found to be significantly better than at the 40 yard range, both in the case of radial miss distance and in the case of number of target hits. The mean radial distance for 20 and 40 yards, was 14.19 inches and 17.88 inches, respectively. The target hits registered 56.2% for 20 yards and 24.4% for 40 yards.

D. QUESTIONNAIRE RESULTS

Results of the post-test questionnaires completed by the Ss indicated a significant ordering of sight preferences (α = .10) overall, but no significant preference ordering at either the 20 or 40 yard range. The indicated overall preference was as follows: 1) small circular bracketing sight, 2) unmodified sight, and 3) large circular bracketing sight. The profile information gave some indication into these preferences. All of the Ss stated that their primary military weapons training was with the M16A1 rifle which has the standard rifle "peep" sight, and furthermore that 84% had extensive civilian hunting experience with shotguns (bead sights).

V. CONCLUSIONS

A circular bracketing type sight of the appropriate size on the M12 riot shotgun can significantly decrease the radial distance between the center of the aiming point and the center of mass of the shot burst when firing #00 buckshot. Furthermore, the use of a circular bracketing sight will greatly increase the number of pellet hits on target.

The effectiveness of the unmodified sight deteriorated rapidly with range in regard to target hits. The bracketing aid's advantage is apparently increased with range.

Results of user preferences were generally inconclusive and appeared to be affected by the user's previous shooting experience.

VI. RECOMMENDATIONS

A. OPTIMAL SIZE

Although the large bracketing sight gave the best performance in terms of radial miss distance, and both bracketing sights were significantly superior to the unmodified sight in terms of target hits, there was no indication that the sizes of these sights was optimal. Various sizes of the bracket should be investigated to attempt to establish an optimal configuration for use in civil disturbance operations.

B. TYPE OF ENGAGEMENT

It has been suspected that, in a quick-reaction environment, it would be easier to place a target inside a bracket than it would be to align a bead sight as in the current standard shotgun configuration. This present research indicated that when firing on stationary targets, the bracketing sights could provide smaller miss distances and an increased number of pellet hits on the target. The logical step would be to test the concept on moving targets, as these form a significant portion of the targets engaged in civil disturbance operations and previous research suggests an even greater advantage for bracketing sights with moving targets.

C. MEASURE OF EFFECTIVENESS

Future researchers in this area would do well to develop a measure of effectiveness which incorporates both of the methods used in this research into one measure. This would aid in resolving conflicts between the two measures and would provide a technique for weighting the shot which is on target and low more heavily than a shot which is wide of the target. The latter would obviously provide a greater threat to unintentional targets than the former.

VII. TECHNICAL SUPPLEMENT

A. PERSONNEL AND EQUIPMENT

1. Subjects

Six military personnel, three provided by Training Command, U. S. Army Training Center, Fort Ord, California; and three provided by Enlisted Company, Naval Postgraduate School, Monterey, California, were used as Subjects (Ss) for this experiment. Each S had previous shotgun firing experience of either a military or civilian nature. No other special selection criteria were utilized.

2. Weapons and Ammunition

Five M12 12-gage riot shotguns were obtained from the 54th Military Police Company, Fort Ord. Two weapons were modified with the addition of circular bracketing sights and the remaining three were unmodified. Two of the three unmodified weapons were maintained as a reserve in the event of a weapon malfunction. No weapon malfunctions did occur during the conduct of the test firing. All weapon slings were removed during the course of experimentation.

Ammunition was locally purchased standard 12-gage #00 buckshot containing nine pellets of approximately .30 caliber per round. This type ammunition was the prescribed military load for riot control operations [3]. In addition, ammunition such as #7½ or #9 birdshot has even greater

pattern dispersion and more pellets per round [12]. The relatively small number of pellets per round in #00 buckshot also aided greatly in determining the center of mass of each burst during the data collection phase.

3. <u>Sight Configurations</u>

Three sight configurations were contrasted. These were the standard (bead) sight, the 2.464 inch diameter circular bracketing sight (large), and the 1.232 inch diameter circular bracketing sight (small). The dimensions of the large sight were selected in order to provide a vision field of 180 inches at 40 yards, or approximately six shot pattern diameters. The small sight gave a vision field of 90 inches at 40 yards, or approximately three shot pattern diameters. These vision fields were selected on the basis of #00 buckshot patterns at 40 yards. Previous research on bracketing sights for the M16A1 rifle in a quick-fire mode suggested the use of circular shapes for the bracketing sights due to the resemblance between rifle quick-fire techniques and standard shotgun firing techniques. The bracketing sights were constructed to specifications in the Mechanical Engineering Lab, Naval Postgraduate School.

4. <u>Range Equipment and Operation</u>

Range facilities and targets were obtained through the Directorate for Plans and Training, U. S. Army Training Center, Fort Ord. Targets utilized were standard (Type E) silhouettes modified by the addition of a 2.5 inch diameter aiming point attached to the center of the target. Target

raising mechanisms and control wiring were in place on the ranges and all safety personnel were provided by Training Command, Fort Ord. Figure 9 illustrates the target configurations.

Three targets were placed in raising mechanisms and three firing points were established on firing lines at 20 and 40 yards from the lines of targets as shown in Figure 10. Target operation was controlled from a permanent tower to the rear of the firing lines. Targets were raised on command and exposed for a period of 2.5 seconds. The two ranges of 20 and 40 yards were selected as representative of engagement ranges during the conduct of civil disturbance operations [1]. In addition, all pattern dispersion data in the United States has been compiled at a standard range of 40 yards [12].

All firing was conducted on Range 4 and Range 6. The terrain was level and sparsely vegetated. The weather during the conduct of the firing was mild with temperatures in the 60 - 70 degree range and negligible wind. All testing was conducted under normal daylight conditions.

Emplaced 4 feet to the rear of each target was a 6 x 10 foot frame covered with cardboard in order to catch all pellets fired and to assist in data collection. The panel frames were constructed to specifications by the Public Works Shop, Naval Postgraduate School. The panels were effectively four pattern widths wide and 2½ pattern widths high. They were of sufficient size to catch all

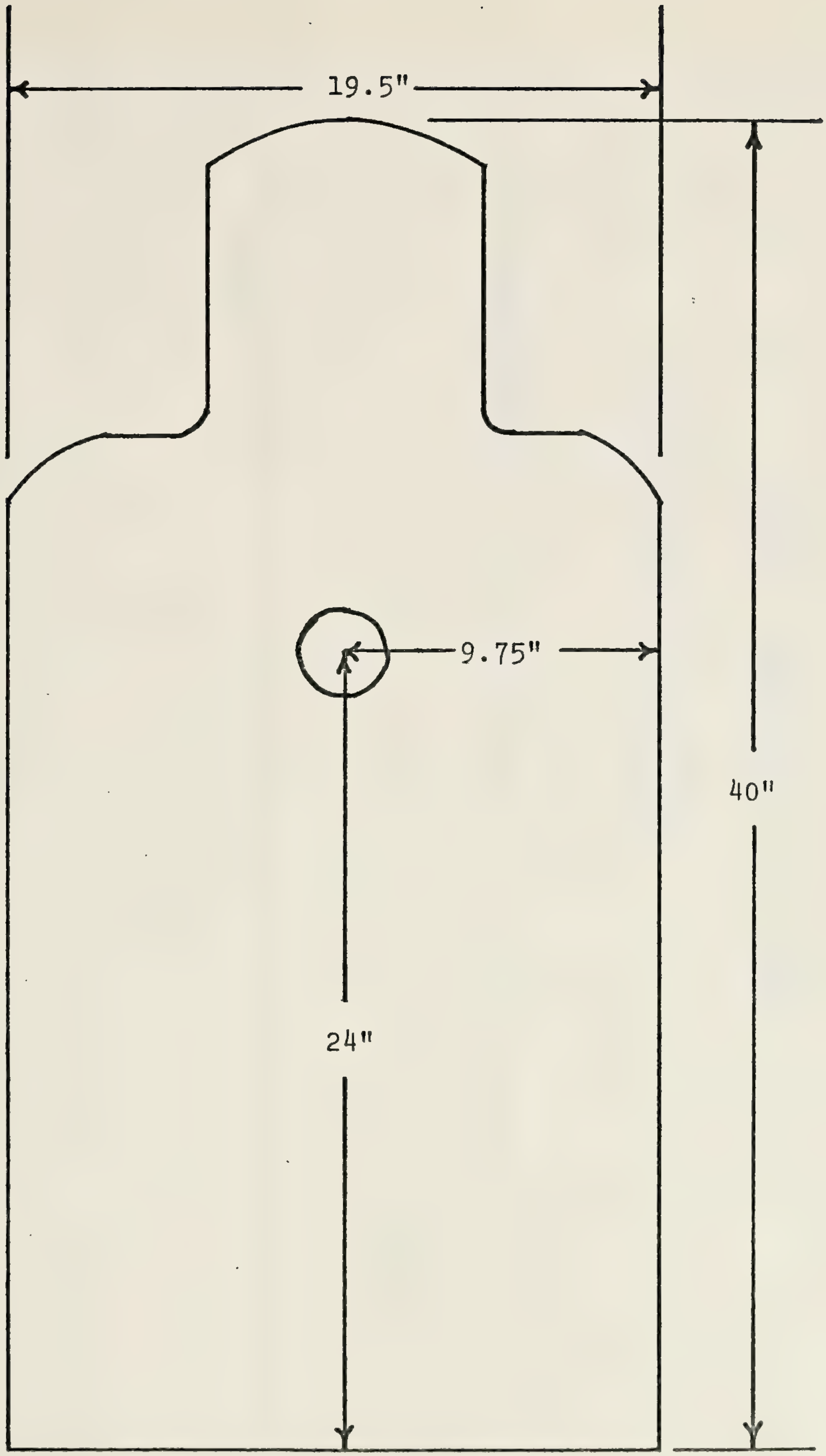

Figure 9. Dimensional Sketch of Silhouette Target

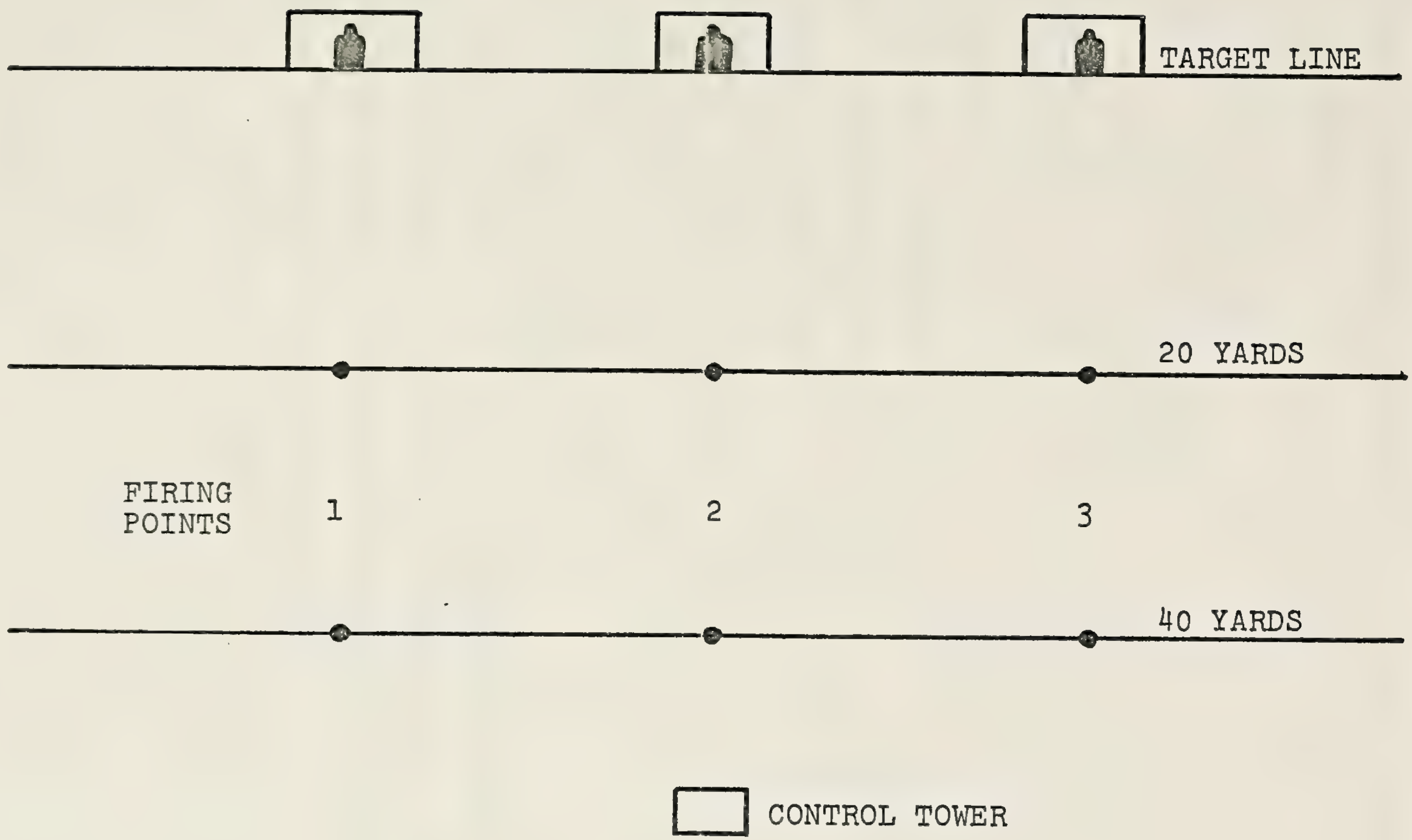

Figure 10. Firing Range Diagram

pellets fired except for those low into the ground. The panels were patched after each round fired with standard target patches and replaced as necessary throughout the test firing.

B. TEST PROCEDURE

1. Experimental Design

The basic design used for the experiment was a four-way factorial random block design. Subjects (Ss) were considered as a random factor, with range, sight configuration, and trial considered as fixed factors. A secondary design was a three-way factorial random block design for determining target hit significance. The experiment was planned to provide conditions similar to civil disturbance type operations, namely level terrain and short-range, quick-reaction firing on silhouette targets.

2. Test Variables

The test variables selected were sight configuration, range to target, and trial. The small circle, large circle and bead sights were selected as the sight configurations based primarily on previous research.

Two ranges to target were utilized, 20 and 40 yards. The majority of targets encountered in riot control situations are at ranges of less than 30 yards, and the accuracy of a shotgun is greatly reduced beyond a range of 50 yards. The two ranges used were selected as being representative

of situations encountered in operations of a civil disturbance nature.

Four rounds were fired at each target for a particular range and sight configuration by each S, thus each round was considered a trial within treatments. This provided a means of determining if any learning effects were confounding the results for each condition a S underwent. The assignment of test conditions to the Ss in a random manner negated any learning effects which may have occurred during the conduct of the entire test.

3. Measures of Effectiveness

The primary measure of effectiveness used was the radial miss distance. This was defined as the straight line distance between the center of the aiming point on the target and the center of mass of each shot burst. This measurement was taken by means of a transparent template etched with circles of diameters varying from 10 to 30 inches, in 5 inch increments. Since measurements were taken after each round fired, the template was simply placed over the pellet pattern on the cardboard panel and shifted until all pellets fell within one of the circles. The center was located, marked and used as an indication of center of mass for the pellets. As this measure did not sufficiently differentiate between shots on line with the target and misses to the left or right, a secondary measure of effectiveness, pellet hits on target, was adopted. These

data were collected upon the completion of firing of four rounds by each S with each combination of range and sight configuration.

C. CONDUCT OF THE EXPERIMENT

1. Orientation

Upon arrival at the range, the Ss were given an orientation briefing (Appendix A) consisting of background information, an explanation of the problem, a range orientation, and a description of test procedures. Upon completion of the orientation, instruction was given on the operation of the weapons, the use of the modified sights, and safety precautions to be observed on the range. The Ss were then lead through a dry-fire exercise in which corrections were made on their body-weapon-target alignment and questions were answered.

2. Familiarization Firing

Familiarization firing was conducted which enabled each S to fire three rounds with each of the sight configurations in order to familiarize himself with the proper body-weapon-target alignment and to provide him with the opportunity to adjust his aiming point in order to best attempt to center the shot burst on the aiming point provided on the target. It was found that a total of 12 rounds was quite sufficient to give the Ss a feel for handling the modified weapons and to provide them adequate experience in properly adjusting their aiming points.

3. Test Firing

Upon completion of the familiarization firing, each S was assigned a firing number. The testing was conducted by assigning the Ss, by firing number, to the firing positions with a specified sight configuration. Three Ss fired simultaneously, each using a different sight configuration. Appendix B provides a copy of the firing tables for the test firing. Range, sight configuration, and S order were completely randomized.

When arriving at the firing position, each S was issued one round of ammunition and instructed to lock and load. When all firers were ready, the Ss were instructed to remove the safety and to watch their lanes. When the target appeared, the Ss each fired, then cleared the weapon. After all weapons were cleared, the firing line was closed.

Scoring personnel and firers then moved to the target line. The back of each target was marked with firing number, sight configuration and range, and all target hits were scored with a marking pencil. Radial miss distance measurements were made on the cardboard backing panels, measuring from the center of the target aiming point to the center of mass of the shot burst. All measurements were made to the nearest 1/4 inch. Upon the completion of measurements, target panels were patched, thus enabling successive rounds to be more easily identified and measured. After a particular firing order had fired four rounds, silhouette targets were

replaced and a new firing order was designated. This procedure was repeated until each S had fired four rounds with each of the three sight configurations at both of the designated ranges. A total of 144 rounds was fired during the conduct of the test firing.

4. Post-Test Questionnaire

After completion of all test firing, the Ss were asked to complete prepared questionnaires (Appendix C) concerning general background information, comments on the conduct of the experiment, and individual preferences among the sight configurations tested. The Ss were asked to rank the three sight configurations in order of preference for 20 yards, 40 yards and overall. All comments, both favorable and critical, were encouraged on the questionnaires.

D. ANALYSIS OF DATA

1. Radial Miss Distance

The data on radial miss distance was collected in 144 cells. Each cell described the radial miss distance for a particular S, using a particular sight configuration, at a particular range, on a particular trial. The radial miss distance was measured as straight line distance from the center of the target aiming point to the center of mass of the shot pattern for each round fired. The data from the 144 cells was tested for normality using a χ^2 Goodness of Fit Test and was found to have a significant fit (α=.10) to the N(16,49) distribution [10]. Table III lists the data

TABLE III. TABLE OF OBSERVED RADIAL MISS DISTANCE DATA

1. SIGHT CONFIGURATION — UNMODIFIED

Range — 20 Yards

Subject	Trial 1	2	3	4
1	12.00	9.00	8.50	13.00
2	12.00	16.50	19.00	17.00
3	13.00	15.00	10.50	12.00
4	18.50	16.50	14.50	3.75
5	11.25	27.50	11.75	14.25
6	16.00	20.00	18.00	0.00

Range — 40 Yards

Subject	Trial 1	2	3	4
1	26.00	26.50	9.50	18.50
2	20.00	13.50	25.50	21.00
3	16.00	19.50	17.00	11.00
4	19.00	26.00	16.00	24.00
5	20.00	30.00	28.00	20.00
6	21.00	16.00	17.00	18.00

TABLE III. TABLE OF OBSERVED RADIAL MISS DISTANCE DATA (Continued)

2. SIGHT CONFIGURATION – SMALL CIRCULAR BRACKET

Range – 20 Yards

Subject	Trial 1	2	3	4
1	10.50	13.00	14.50	16.50
2	20.00	21.00	18.00	17.00
3	17.00	17.25	15.50	16.00
4	21.00	10.75	22.00	22.50
5	20.00	30.00	18.50	23.00
6	22.00	24.00	15.00	16.00

Range – 40 Yards

Subject	Trial 1	2	3	4
1	17.00	30.00	23.00	12.00
2	15.50	18.00	21.50	16.00
3	23.50	17.00	21.50	28.00
4	19.00	15.00	23.00	28.50
5	25.00	16.25	16.50	30.00
6	10.00	11.00	29.00	12.00

TABLE III. TABLE OF OBSERVED RADIAL MISS DISTANCE DATA (Continued)

3. SIGHT CONFIGURATION — LARGE CIRCULAR BRACKET

Range — 20 Yards

Subject	Trial			
	1	2	3	4
1	9.00	5.00	4.00	8.50
2	5.00	9.50	11.50	0.00
3	11.00	7.00	16.50	13.00
4	7.00	22.00	10.00	10.50
5	17.75	14.00	5.00	5.50
6	6.25	17.50	20.00	16.00

Range — 40 Yards

Subject	Trial			
	1	2	3	4
1	10.00	13.50	14.50	9.00
2	7.25	16.00	18.00	8.00
3	16.00	16.00	12.50	14.00
4	12.00	16.00	8.25	23.00
5	12.75	13.50	10.00	18.00
6	13.50	12.75	16.00	19.50

by cells. The radial distance for the first S is listed first, the second S is listed second, and so on. The four-way factorial design resulted in only one item of the data in each cell [7]. The model utilized for the conduct of analysis of variance was as follows:

$$X_{ijkl} = \mu + R_i + C_j + S_k + T_l + RC_{ij} + RS_{ik} + RT_{il} +$$
$$CS_{jk} + CT_{jl} + ST_{kl} + RCS_{ijk} + RCT_{ijl} +$$
$$RST_{ikl} + CST_{jkl} + \varepsilon_{m(ijkl)}$$

where

R = range   C = configuration   S = subject   T = trial

ε = error μ = mean   i = 1,2   j = 1,2,3   k = 1,2,3,4,5,6

l = 1,2,3,4   m = 1

The calculations were performed using an IBM 360 computer and the BMD02V program prepared by the Health Sciences Computing Facility, University of California at Los Angeles, revised 12 September 1969 [4].

A level of significance of α=.05 was selected for testing the data. Table IV gives the results of the analysis. The null hypotheses tested were that there was no main effect due to each variable independently, and that there were no significant effects due to interactions among the variables. These were tested against alternate hypotheses that there

TABLE IV. ANALYSIS OF VARIANCE FOR 4-WAY FACTORIAL RANDOMIZED BLOCK DESIGN (RADIAL MISS DATA)

VARIABLE	NO. LEVELS	d.f	SS	MS	F
(1) range	2	1	488.59413	488.59413	16.947**
(2) sight	3	2	1235.20563	617.60278	19.964***
(3) subject	6	5	272.96221	54.59244	
(4) trial	4	3	86.19227	28.73074	1.107
INTERACTIONS					
1 x 2		2	134.32374	67.16187	4.580*
1 x 3		5	144.15314	28.83061	
1 x 4		3	84.07447	28.02481	0.814
2 x 3		10	309.35162	30.93515	
2 x 4		6	160.26987	26.71164	0.887
3 x 4		15	389.01871	25.93457	
1 x 2 x 3		10	146.63998	14.66400	
1 x 2 x 4		6	63.53398	10.58900	0.467
1 x 3 x 4		15	516.45953	34.43063	
2 x 3 x 4		30	903.02715	30.10089	
1 x 2 x 3 x 4 (residual)		30	680.25391	22.67513	
	TOTAL	143	5614.05859		

*Significant for $\alpha = 0.05$

**Significant for $\alpha = 0.01$

***Significant for $\alpha = 0.001$

were main effects or interactions. The numerical values of the resulting F-ratio tests are given in Table V.

The fact that there were more than two levels of some variables considered made it impossible to determine from the analysis of variance between which levels significant differences existed. In order to make this determination, the Newman-Keuls Range Test was used [7]. Table VI gives the results of this test.

2. Target Hits

The data for number of target hits was collected in 36 cells. Data was collected on the basis of the number of pellet hits on the silhouette targets for four rounds fired by each particular S, at each particular range, and with each particular sight configuration. Since the number of observations in each cell was relatively small (36) and the use of analysis of variance techniques required data which was normally distributed, an arcsine transformation was used to ensure that the cell entries met the requirements of being normal variates. The number of pellet hits per cell was transformed as follows:

$$Y_{ijk} = 2 \arcsin \sqrt{X_{ijk}/36}$$

where

X = number of pellet hits on target $i = 1,2$

$j = 1,2,3$ $k = 1,2,3,4,5,6$

TABLE V. RESULTS OF ANALYSIS OF VARIANCE TEST STATISTICS AND HYPOTHESIS TESTING FOR RADIAL MISS DISTANCE DATA

TEST		TEST STAT VALUE	DISTRIBUTION UNDER H_0	$F_d^n(.05)$	RESULT
1. H_0: No effect H_1: Range effect	MS_1/MS_{1x3}	16.947	F(1,5)	6.61*	Reject H_0
2. H_0: No effect H_1: Sight effect	MS_2/MS_{2x3}	19.964	F(2,10)	4.10**	Reject H_0
3. H_0: No effect H_1: Trial effect	MS_4/MS_{3x4}	1.107	F(3,15)	3.29	Cannot reject H_0
4. H_0: No interaction H_1: Range x Sight	MS_{1x2}/MS_{1x2x3}	4.580	F(2,10)	4.10	Reject H_0
5. H_0: No interaction H_1: Range x Trial	MS_{1x4}/MS_{1x3x4}	0.814	F(3,15)	3.29	Cannot reject H_0
6. H_0: No interaction H_1: Sight x Trial	MS_{2x4}/MS_{2x3x4}	0.887	F(6,30)	2.42	Cannot reject H_0
7. H_0: No interaction H_1: Range x Sight x Trial	$MS_{1x2x4}/MS_{1x2x3x4}$	0.467	F(6,30)	2.42	Cannot reject H_0

* For test 1, $F_d^n(.01) = 16.26$, thus H_0 can be rejected at the .01 level of significance.

** For test 2, $F_d^n(.001) = 14.91$, thus H_0 can be rejected at the .001 level of significance.

TABLE VI. NEWMAN-KEULS RANGE TEST (RADIAL MISS DATA)

SIGHT	TREATMENT	MEAN	ERROR MEAN SQUARE	ERROR d.f.	NO. OBS.
Large	1	12.11458	22.67513	30	48
Small	2	19.15103	22.67513	30	48
Unmod	3	16.84375	22.67513	30	48

$\alpha = .05$

TEST	S	p	LEAST SIG RANGE	DIFF	RESULTS
2 vs 1	0.687	3	2.390	7.036	Sig
2 vs 3	0.687	2	1.985	2.307	Sig
3 vs 1	0.687	2	1.985	4.724	Sig

$$S = \sqrt{\frac{\text{error mean square}}{\text{no. of observations per target sight}}}$$

LSR = S x Tabled range value

A test using the arcsine statistic is more nearly normal than just using the proportion $X_{ijk}/36$. Additionally, homogeneity of variance cannot be assumed when using proportional variates. However, if all proportions are based on an equal number of observations, and if each is converted to an angle, as in the arcsine transformation, the homogeneity of variance assumption is valid due to the fact that each angle has the same variance (1/36), even though the proportions may differ [11].

Table VII lists the data by cells. The number in the upper left-hand corner of each cell is the total number of pellet hits for the given S, sight configuration, and range. The normalized values are the primary cell entries. The model used for the subsequent analysis of variance was as follows:

$$X_{ijk} = \mu + R_i + C_j + S_k + RC_{ij} + RS_{ik} + CS_{jk} + \varepsilon_{m(ijk)}$$

where

R = range C = configuration S = subject

ε = error μ = mean $i = 1,2$ $j = 1,2,3$

$k = 1,2,3,4,5,6$ $m = 1$

The calculations were again performed on an IBM 360 computer using the BMD02V program.

TABLE VII. TABLE OF OBSERVED AND NORMALIZED TARGET HIT DATA

1. SIGHT CONFIGURATION – UNMODIFIED

Subjects	Range	
	20 Yards	40 Yards
1	11 1.16951	8 0.98027
2	17 1.51256	3 0.58484
3	15 1.40098	8 0.98027
4	12 1.22898	0 0.00000
5	16 1.45695	2 0.47520
6	25 1.96600	10 1.10850

TABLE VII. TABLE OF OBSERVED AND NORMALIZED TARGET HIT DATA (Continued)

2. SIGHT CONFIGURATION - SMALL CIRCULAR BRACKET

Subjects	Range	
	20 Yards	40 Yards
1	23 1.84855	12 1.22898
2	26 2.02684	17 1.51256
3	29 2.22257	7 0.91196
4	16 1.45695	5 0.76266
5	16 1.45695	3 0.58484
6	29 2.22257	12 1.22898

TABLE VII. TABLE OF OBSERVED AND NORMALIZED TARGET HIT DATA (Continued)

3. SIGHT CONFIGURATION – LARGE CIRCULAR BRACKET

Subject	Range	
	20 Yards	40 Yards
1	28 2.15460	11 1.16951
2	26 2.02684	12 1.22898
3	22 1.79138	17 1.51256
4	13 1.28721	11 1.16951
5	15 1.40098	7 0.91196
6	25 1.96600	13 1.28721

A level of significance of $\alpha = .05$ was selected for testing the data. Table VIII gives the results of the analysis. The null hypotheses tested were that there was no significant main effect due to each variable independently, and that there were no significant effects due to interactions among the variables. These were tested against alternate hypotheses that there were significant main effects or interactions. The numerical values of the resulting F-ratios are given in Table IX.

The Newman-Keuls Range Test was used to determine where significant differences between levels of the variables existed. Table X gives the results of this test.

3. Post-Test Questionnaire

The questionnaire given to each S at the conclusion of the test firing was designed to gather information on background, comments on the conduct of the experiment, and preferences for the three sight configurations. A summary of the questionnaire responses may be found in Appendix D. The Ss' preferences among the tested sight configurations were tested for significant consistency using Kendall's Coefficient of Concordance [9,10]. The results of these tests may be found in Table XI.

TABLE VIII. ANALYSIS OF VARIANCE FOR 3-WAY FACTORIAL RANDOMIZED BLOCK DESIGN (HITS ON TARGET)

VARIABLE	NO. LEVELS	d.f.	SS	MS	F
(1) range	2	1	4.66390	4.66390	114.648*
(2) sight	3	2	1.29965	0.64982	56.1157*
(3) subject	6	5	2.04197	0.40839	
INTERACTIONS					
1 x 2		2	0.12470	0.06235	0.787
1 x 3		5	0.05788	0.01158	
2 x 3		10	0.40680	0.04068	
1 x 2 x 3 (residual)		10	0.79219	0.07922	
	TOTAL	35	9.38709		

*Significant for $\alpha = 0.001$

TABLE IX. RESULTS OF ANALYSIS OF VARIANCE TEST STATISTICS AND HYPOTHESIS TESTING FOR TARGET HIT DATA

TEST	TEST STATISTIC	TEST STAT VALUE	DISTRIBUTION UNDER H_0	$F_d^n(.05)$	RESULT
1. H_0: No effect H_1: Range effect	MS_1/MS_{1x3}	114.648	F(1,5)	6.61*	Reject H_0
2. H_0: No effect H_1: Sight effect	MS_2/MS_{2x3}	56.1157	F(2,10)	4.10**	Reject H_0
3. H_0: No interaction H_1: Range x Sight	MS_{1x2}/MS_{1x2x3}	0.787	F(2,10)	4.10	Cannot reject H_0

* For test 1, $F_d^n(.001) = 47.18$, thus H_0 can be rejected at the .001 level of significance.

** For test 2, $F_d^n(.001) = 14.91$, thus H_0 can be rejected at the .001 level of significance.

TABLE X. NEWMAN-KEULS RANGE TEST (NORMALIZED TARGET HIT DATA)

SIGHT	TREATMENT	MEAN	ERROR MEAN SQUARE	ERROR d.f.	NO. OBS.
Large	1	1.49223	0.07922	10	12
Small	2	1.45537	0.07922	10	12
Unmod	3	1.07201	0.07922	10	12

α = .05

TEST	S	p	LEAST SIG RANGE	DIFF	RESULTS
1 vs 3	.0813	3	.315	0.420	Sig
1 vs 2	.0813	2	.256	0.037	Not Sig
2 vs 3	.0813	2	.256	0.383	Sig

$$S = \sqrt{\frac{\text{error mean square}}{\text{no. of observations per target sight}}}$$

LSR = S x Tabled Range Value

TABLE XI. SUBJECT PREFERENCES AND KENDALL'S CONCORDANCE

$N = 3$

$k = 6$

Range — 20 Yards

Subject		Sight	
	U	S	L
1	2	1	3
2	1	2	3
3	1	2	3
4	3	2	1
5	2	1	3
6	2	1	3
R_j	11	9	16
$(R_j - \Sigma R_j/N)$	-1	-3	+4
$(R_j - \Sigma R_j/N)^2$	1	9	16

$S = 26 = \Sigma(R_j - \Sigma R_j/N)^2$

$$W = .361 = \frac{S}{(1/12)k^2(N^3 - N)}$$

$\alpha = .10$

$S(3,6) = 30 \quad S = 26$

Cannot reject H_0, that is there is no significant agreement in preference

TABLE XI. SUBJECT PREFERENCES AND KENDALL'S CONCORDANCE (Continued)

$N = 3$

$k = 6$

Range — 40 Yards

Subject	Sight		
	U	S	L
1	3	1	2
2	1	2	3
3	2	1	3
4	3	2	1
5	2	1	3
6	2	1	3
R_j	13	8	15
$(R_j - \Sigma R_j/N)$	1	-4	3
$(R_j - \Sigma R_j/N)^2$	1	16	9

$S = 26 = \Sigma(R_j - \Sigma R_j/N)^2$

$$W = .361 = \frac{S}{(1/12)k^2(N^3 - N)}$$

$\alpha = .10$

$S(3,6) = 30 \quad S = 26$

Cannot reject H_0, that is there is no significant agreement in preference

TABLE XI. SUBJECT PREFERENCES AND KENDALL'S CONCORDANCE (Continued)

$N = 3$

$k = 6$

Range — Overall

Subject		Sight	
	U	S	L
1	2	1	3
2	1	2	3
3	2	1	3
4	3	2	1
5	2	1	3
6	2	1	3
R_j	12	8	16
$(R_j - \Sigma R_j/N)$	0	-4	4
$(R_j - \Sigma R_j/N)^2$	0	16	16

$$S = 32 = \Sigma(R_j - \Sigma R_j/N)^2$$

$$W = 0.444 = \frac{S}{(1/12)k^2(N^3 - N)}$$

$\alpha = .10$

$S(3,6) = 30$ $S = 32$

Reject H_0, a significant agreement in preference exists

Rank	Sight
1	Small
2	Unmodified
3	Large

APPENDIX A: ORIENTATION

I. INTRODUCTION/WELCOME

Gentlemen, I am CPT Read. I appreciate the fact that you are here today and I hope that you, as participants, will find this experiment interesting. It is felt the experimental results may be a significant contribution towards improving the effectiveness of the M12 riot shotgun. Basically the experiment is designed to test the M12 shotgun modified with two sizes of circular bracketing sights, as shown here, against the standard bead sight. You will be firing at stationary silhouette targets at short ranges. I will be interested not only in your shooting performance, but also your personal views on the sight systems.

The experiment will consist of firing the M12 shotgun with each of the three sight configurations at targets at ranges of 20 and 40 yards. The target will be exposed for 2.5 seconds for each trial. I shall now discuss the firing techniques to be used.

II. LECTURE PRESENTATION/DEMONSTRATION

There are two methods of fire to be used in this experiment. The first is the standard shotgun firing technique with which you are all familiar. You will use this method when firing the standard or unmodified sight.

The second technique will involve a slight modification of standard methods and will be used when firing with the bracketing sights.

When using either of the bracketing sights, center your target inside the circle, attempting to place your aiming point directly in the center of the circular bracket. You will have an opportunity during the familiarization firing to practice this method. The weapon will initially be carried at high port. Distribute your weight equally on both feet. Bring the weapon to your shoulder and obtain a good stock weld. Close your left eye and center the target within the bracket as described before.

Watch the demonstrator go through the steps!

Are there any questions on either of the techniques?

III. EXPLANATION OF THE RANGE OPERATION

Now that we have considered the techniques of fire, I would like to explain the range operation for this experiment. (Show diagram of the range. Point out salient features.)

1. The targets are standard silhouettes. On each target is located a white circular aiming point.

2. The target will stay up for 2.5 seconds.

3. Panels behind the targets will record all shot-pellet hits.

4. Three firing positions are located at each of the distance lines, 20 yards and 40 yards.

IV. EXPLANATION OF FIRING PROCEDURE

1. You will be assigned a subject number for the test firing. Remember this number. It will determine your sequence and position for firing at each range.

2. When your subject number is called, you will draw the weapon with the designated sight and proceed to one of the firing positions at the designated range.

3. You will be issued one round of 12-gage #00 buckshot.

4. Load your weapon on command.

5. Fire when your target appears.

6. Clear your weapon and have it checked by range personnel.

7. On command, firers will proceed downrange to the targets.

8. Your target will be marked with your subject number, sight and range.

9. Measurements will be taken on the panels behind the targets. After measurements have been taken, patch the panels and return to your firing position.

10. This procedure will be repeated four times.

11. After firing four rounds and patching the panels, remove your target and place a new target in the raising mechanism.

12. Return your weapon to the rack and place your completed target to the rear of the firing line.

13. You will fire 4 rounds with each of the 3 sight configurations at both 20 yards and 40 yards.

V. SAFETY

Safety briefing given by Range Safety OIC.

VI. SUMMARY/CONCLUSION

1. Are there any questions that you may have concerning any portion or phase of the experiment?

2. Is there any area of firing techniques you don't understand or would like to see demonstrated again?

3. I want each of you to always be safety conscious when handling the weapon. Do the best you can when firing. The experimental data and subsequent knowledge gained from your participation will assist others in comparing the effectiveness of the different sight configurations. Other experiments will probably follow and those will try to compare their results with what will be done here today. Finally I want you to seriously consider your preferences for the different sights in filling out a questionnaire on the experiment at the end of firing today.

APPENDIX B: TEST FIRING TABLES

Order #1 - 20 Yards	
Subject	Sight
1	L
2	S
3	U

Order #2 - 20 Yards	
Subject	Sight
4	U
5	S
6	L

Order #3 - 40 Yards	
Subject	Sight
2	S
4	U
6	L

Order #4 - 40 Yards	
Subject	Sight
6	U
3	L
4	S

Order #5 - 20 Yards	
Subject	Sight
1	S
4	L
6	U

Order #6 - 20 Yards	
Subject	Sight
2	U
5	L
3	S

Order #7 - 40 Yards	
Subject	Sight
1	U
2	L
6	S

Order #8 - 40 Yards	
Subject	Sight
3	U
5	L
1	S

Order #9 - 40 Yards	
Subject	Sight
1	L
3	S
5	U

Order #10 - 40 Yards	
Subject	Sight
4	L
5	S
2	U

Order #11 - 20 Yards	
Subject	Sight
1	U
3	L
4	S

Order #12 - 20 Yards	
Subject	Sight
6	S
2	L
5	U

APPENDIX C: POST-TEST QUESTIONNAIRE

This questionnaire is designed to obtain information about each person performing in the experiment. Some questions are specific and should be answered as accurately as possible. Other questions ask for the personal views of the firer on aspects of the experiment.

In filling out the questionnaire, try to be as accurate and express YOUR views as best you can. There are no "right" answers. Each person's views are equally important. Take your time and write or print clearly in the spaces provided. If some questions do not apply, put an N/A in the blank space.

I. Background

1. NAME ____________________________

2. RANK ____________________________

3. Subject Number _______________

4. MOS ___________________

5. Age at last birthday

6. Number of years on active duty

7. Are you right handed ______ or left handed ________

8. Do you wear glasses or contact lenses YES NO

9. Do you currently have a physical profile? YES NO
   If YES, please explain.

10. Have you had any special weapons training? YES NO
    If YES, please explain.

11. Are you a member of the NRA? YES NO

12. Do you own a weapon? YES NO if YES, what type?

13. Have you ever hunted with a shotgun?
    Never   3-5 times   Over 10 times
    Once or twice   6-10 times

14. Would you say the community in which you were raised was URBAN RURAL?

II. Comments on the Experiment

15. Do you feel there is a need for a new type sight on a shotgun? YES NO Briefly tell why

16. Do you feel the idea of bracketing targets with a special sight is a valid concept? YES NO Please explain your answer.

17. Do you think the way the test was run will help to determine which sight is best? YES NO Please explain your answer.

18. Was the target exposure time:

    ________ Too short

    ________ Too long

    ________ Adequate

    ________ Other (Explain)

19. Was the orientation prior to the experiment helpful in understanding what the experiment was about?

    YES NO Comments:

20. Was the familiarization firing helpful in your performance? YES NO Please explain your answer.

III. Preferences

21. Rank the three sights (Large circle, small circle, bead) in YOUR order of preferences for the conditions indicated:

20 Yards	40 Yards	Overall
1.	1.	1.
2.	2.	2.
3.	3.	3.

22. Please use the remaining space to make any additional comments concerning the conduct of the experiment, problems you may have experienced, things you liked or disliked about the sights, etc.

THANK YOU FOR YOUR HELP IN PERFORMING THIS EXPERIMENT!

APPENDIX D: SUMMARY OF POST-TEST QUESTIONNAIRE RESPONSES

I. Background

1. NAME: Joe Soldier
2. RANK: E4
3. Subject Number: 1 - 6
4. MOS: Varied
5. Age: Mean = 21.67
6. Years on active duty: Mean = 2.33
7. Right handed: 83%
8. Glasses or contact lenses: 50% YES
9. Current physical profile: One P3 profile following knee surgery
10. Special weapons training: 100% NO
11. NRA member: 100% NO
12. Own weapon: 67% YES Type: rifles, pistols, shotguns
13. Hunted with shotgun: 17% once or twice, 83% over 10 times
14. Community in which raised: 33% Urban 67% Rural

II. Comments on Experiment

15. Need for new shotgun sights: 67% YES, 33% NO

    Comments: aids in locating target, helpful for inexperienced shooters

16. Bracketing as a valid concept: 83% YES, 17% NO

    Comments: gives indication of area of dispersion, aids in aiming, valid if designed into weapon, no sights are needed on shotguns

17. Experiment helpful in sight evaluation: 100% YES

18. Target exposure time: 17% Too short, 33% Adequate, 50% Too long

19. Orientation helpful: 100% YES

20. Familiarization firing helpful, 83% YES, 17% NO

Comments: unnecessary for anyone who has fired a shotgun before, helpful in adjusting aiming point

III. Preferences

21. Sight preferences:

	Sight Rank	U	S	L
20 Yards	1.	2*	3	1
	2.	3	3	0
	3.	1	0	5
40 Yards	1.	1	4	1
	2.	3	2	1
	3.	2	0	4
Overall	1.	1	4	1
	2.	4	2	0
	3.	1	0	5

* Entries are number of subjects assigning indicated rank to each sight configuration.

22. Additional comments:

"Tests should be run with moving targets."

"More rounds should be fired with each sight."

"Firing should not be done only from standing position."

LIST OF REFERENCES

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